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Title: Broadband Operation of Acoustic Collimated Beam Source

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Broadband Operation of Acoustic Collimated Beam Source

Presenter: Sincheng Huang

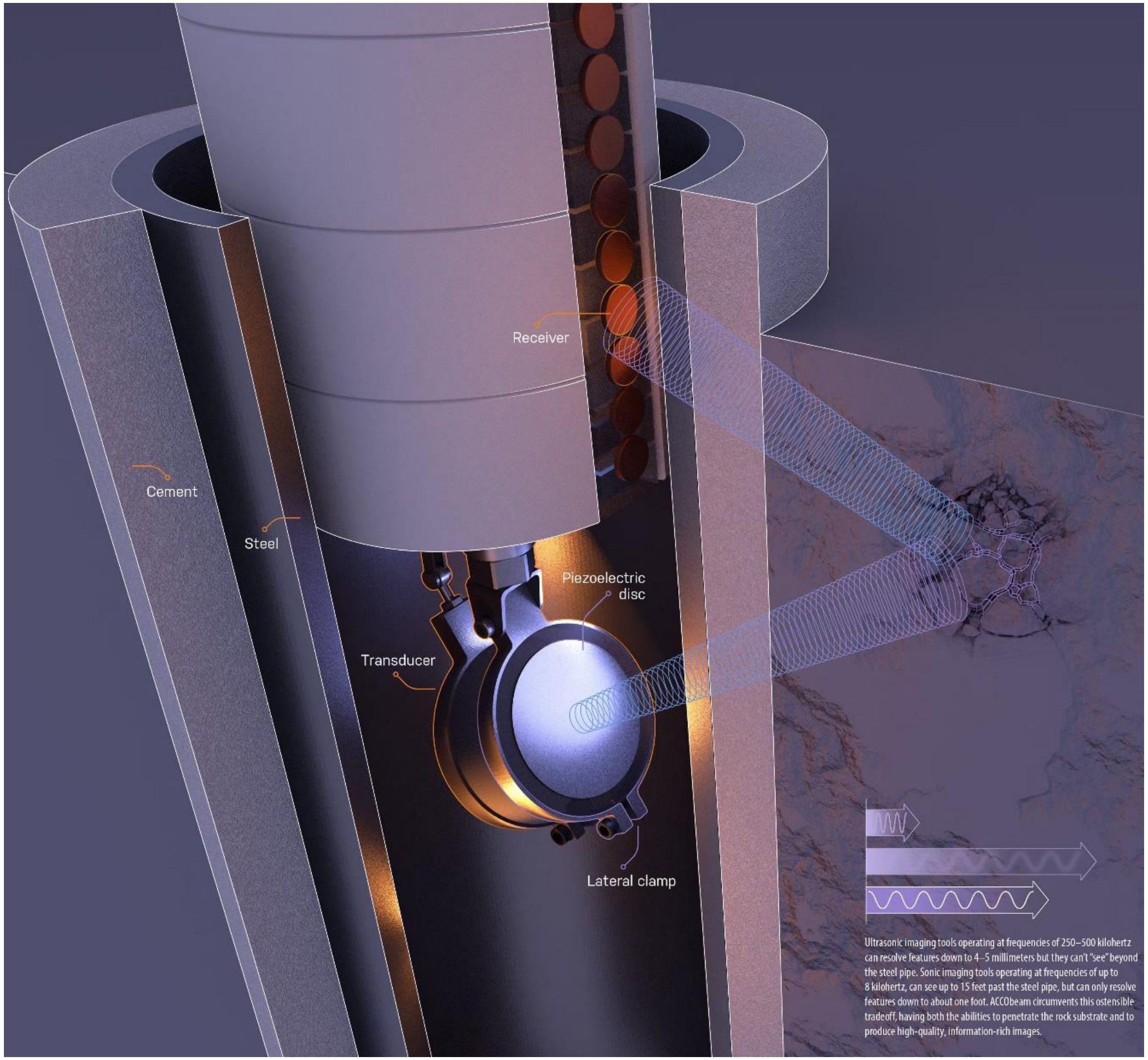
June 10, 2021

LA-UR-xx-xxxxx

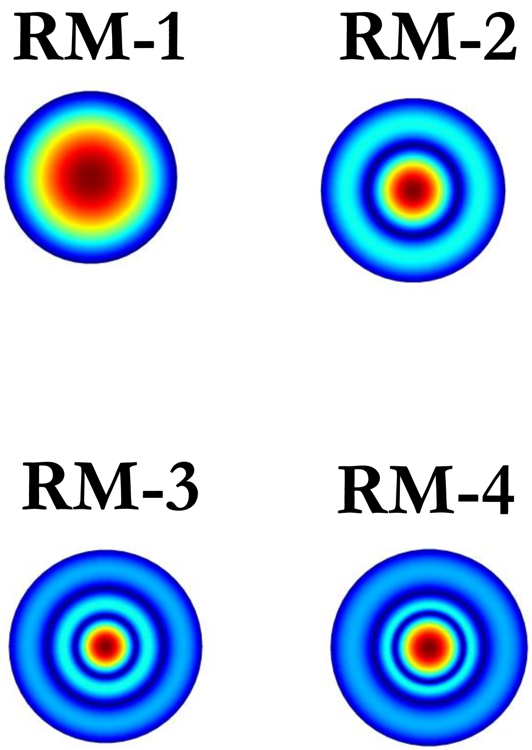
Outline

- Background
- Experimental Setup & Data Analysis
- Fixed Frequency vs Broadband Results
- Reconstructing Acoustic Data

Background – ACCObeam

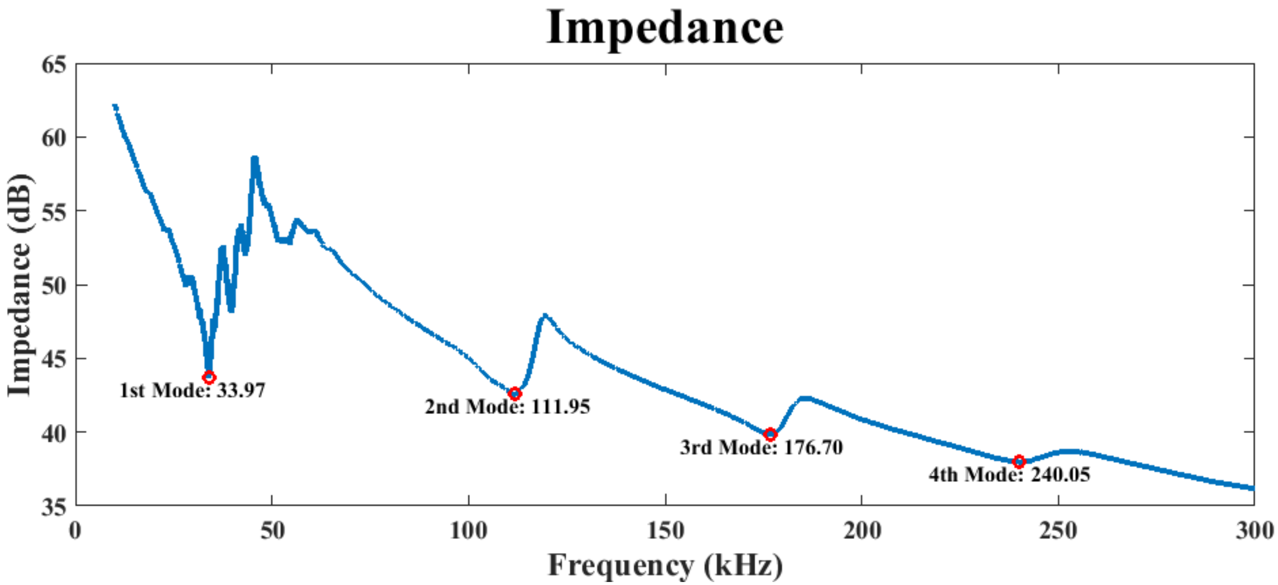


Utilizes radial modes of laterally stiffened piezoelectric discs



Background – ACCObeam

- Impedance measurement to find resonant frequencies



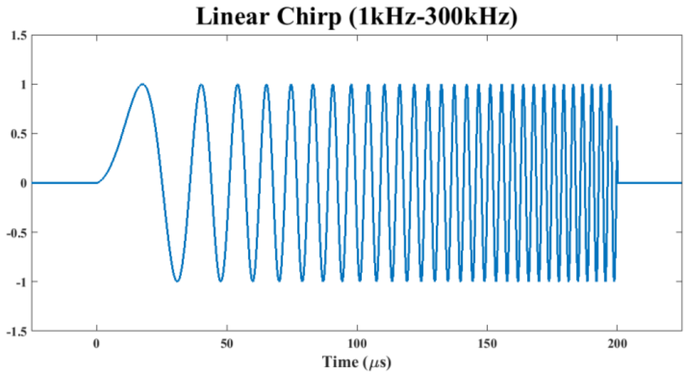
- 1st mode: 34.0 kHz, 2nd mode: 112.0 kHz, 3rd mode: 176.7 kHz, 4th mode: 240.1 kHz

Background – Broadband Signals

- Linear Chirp
  - Instantaneous frequency that increases linearly from the start frequency f_0 to the end frequency f_1 over some period T:

$$f_{lin}(t) = \sin\left(\frac{(f_1 - f_0)\pi}{T}t^2 + 2\pi f_0 t\right)$$

  - Windowing function applied after
    - Rectangle window zeroes signal outside of t=[0,T]
    - Tukey window uses cosine half lobes

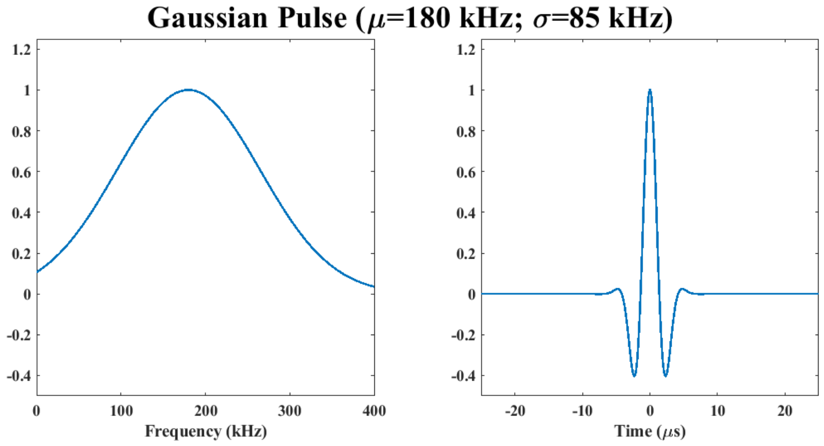


Background – Broadband Signals

- Gaussian Pulse
  - By convolution theorem, a frequency shifted Gaussian in Fourier space is a Gaussian enveloped cosine in time:

$$e^{-\frac{1}{2}\left(\frac{\omega-\mu}{\sigma}\right)^2} \overset{\mathcal{F}}{\leftrightarrow} e^{-\frac{(\sigma t)^2}{2}}\cos(\mu t)$$

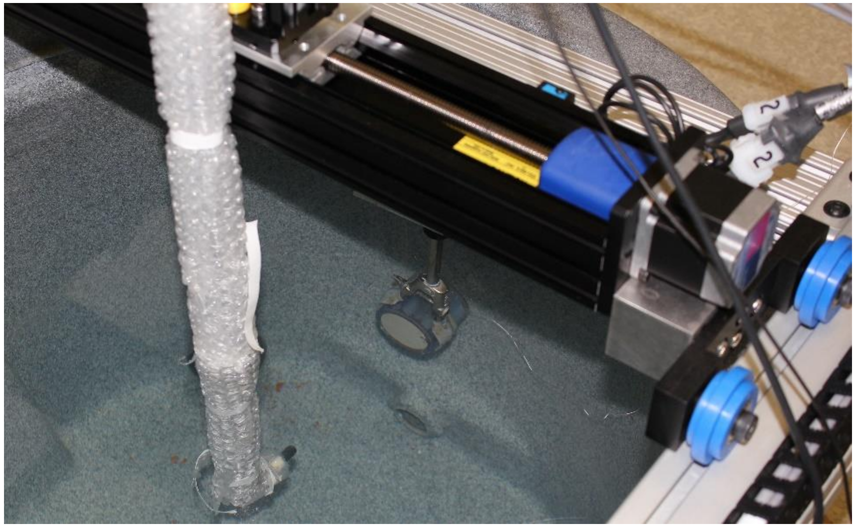
  - Illustrates why use broadband signals – wider spread in frequency domain leads to tighter waveforms in space/time



Experimental Setup

- Clamped transducer mounted near wall of reservoir of water connected to waveform generator
- Hydrophone rigged to translation stage and connected to oscilloscope
  - Set up to move equally spaced intervals across transducer face in a plane of the reservoir
  - Controlled programmatically
- Time measurement taken at each spatial point, averaged over 32 waveforms

Experimental Setup



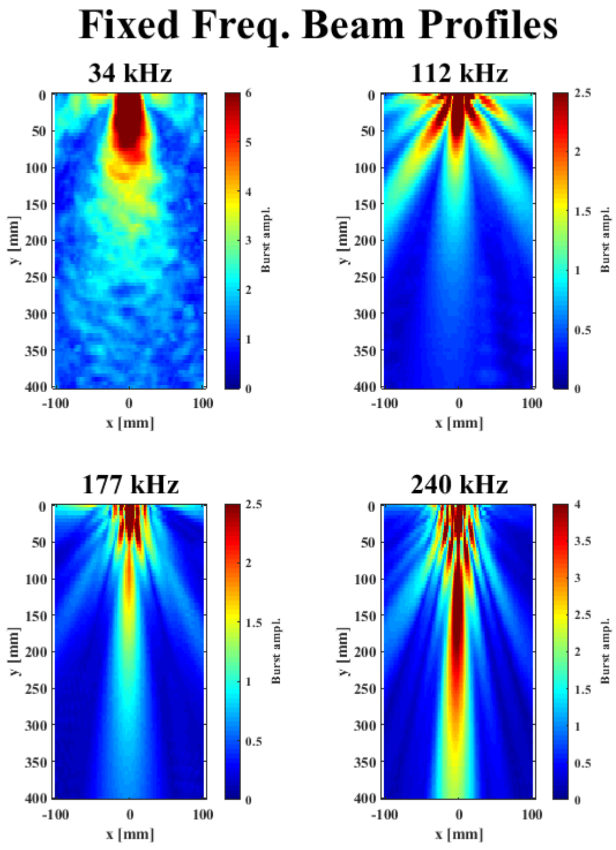
- Hydrophone and translation stage positioned in front of transducer.
- Hydrophone records a “slice” of the beam profile

Data Acquisition and Analysis

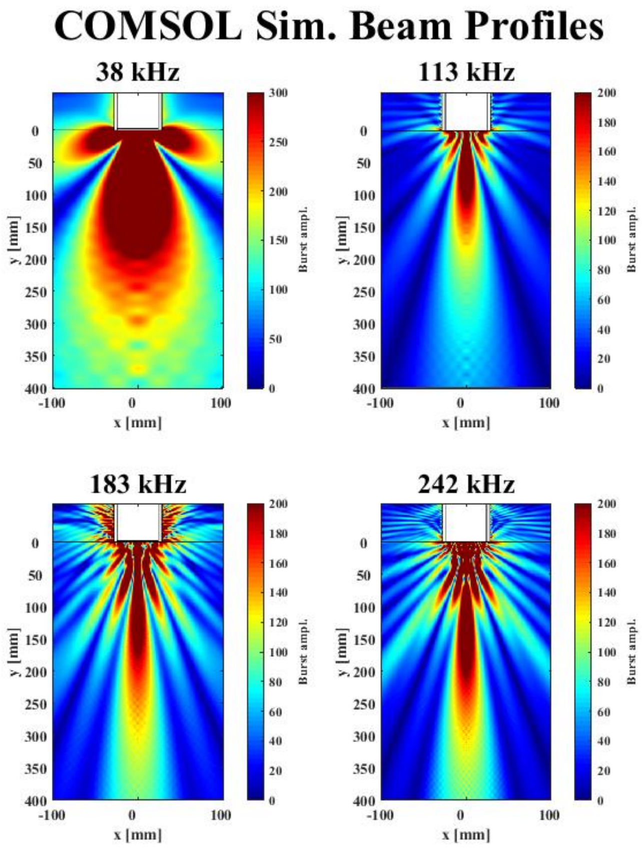
- Measurement time scales with spatial resolution
- Time data post-processed to plot beam-profile
  - Fixed Frequency
    - Maximum peak to peak measurement at each spatial point extracted and plotted
  - Broadband
    - Cross-correlation of measured time data and input waveform to select first-arrival
    - Each time array is Fourier transformed into the frequency domain
    - Amplitude of frequency at each spatial point plotted
    - Animated as GIFs

Fixed Frequency:
Experiments and Simulations

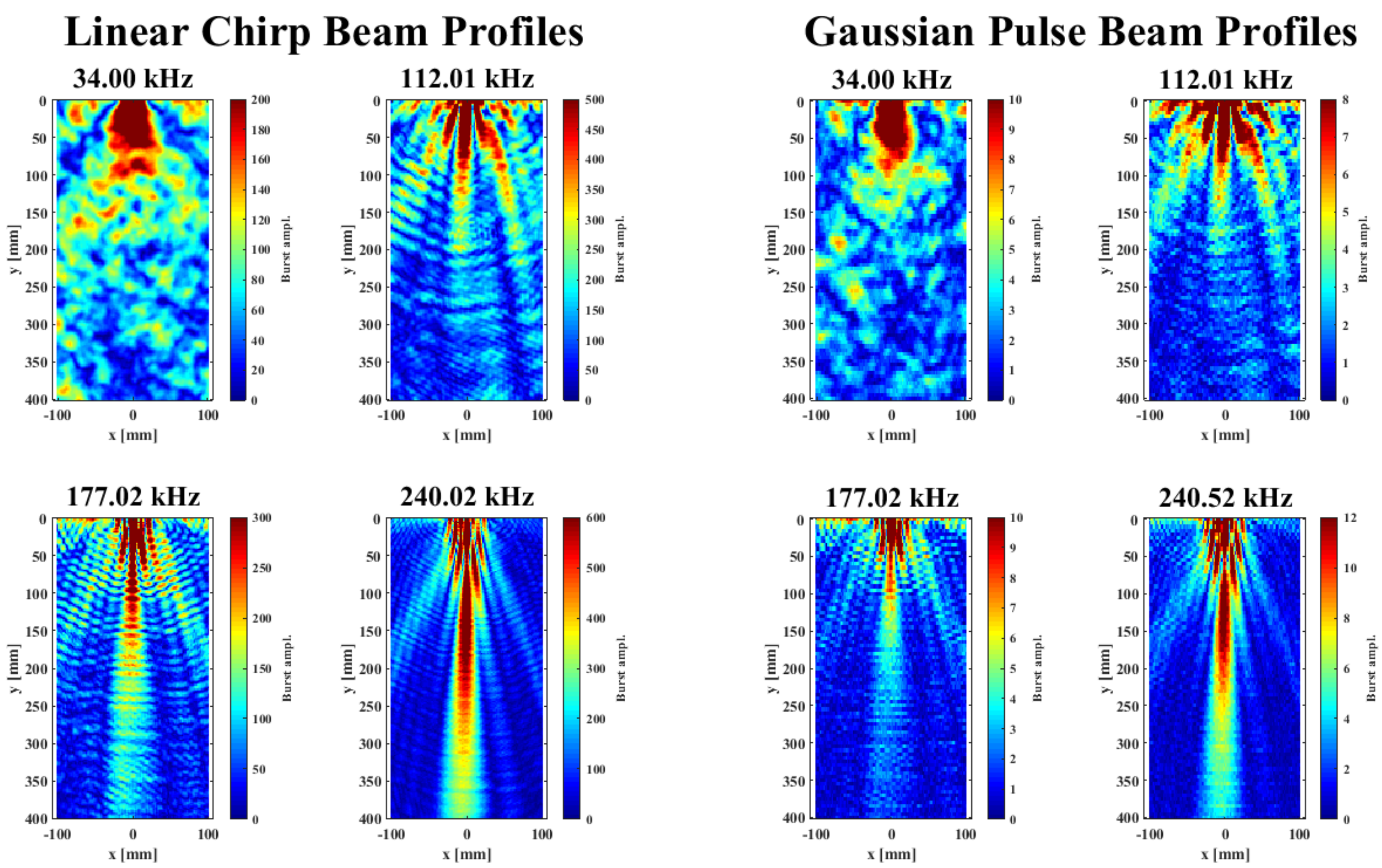
Experiments



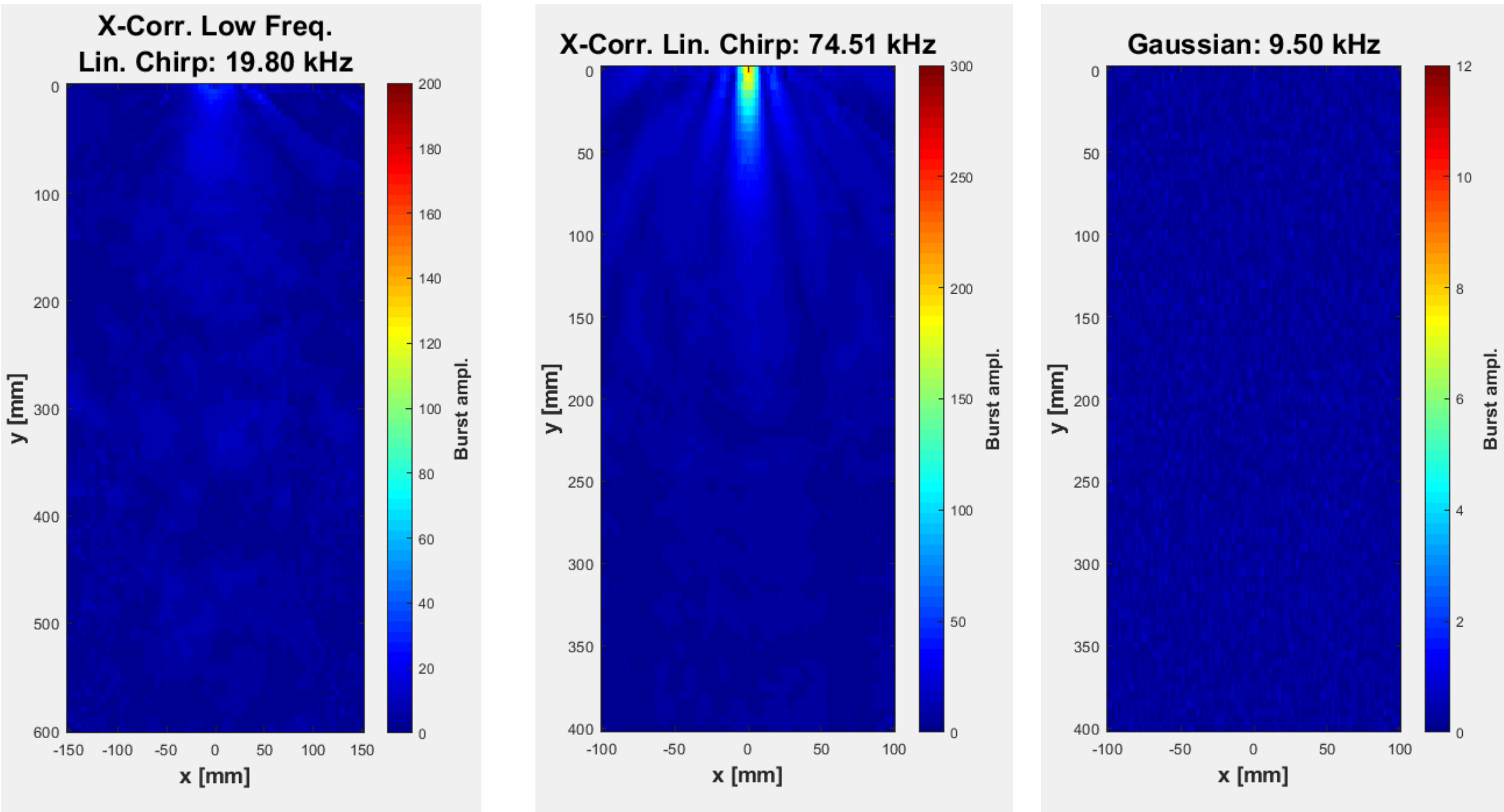
Simulation



Experiments:
Extracted Freq. Beam Profiles



Extracted Frequency Animations



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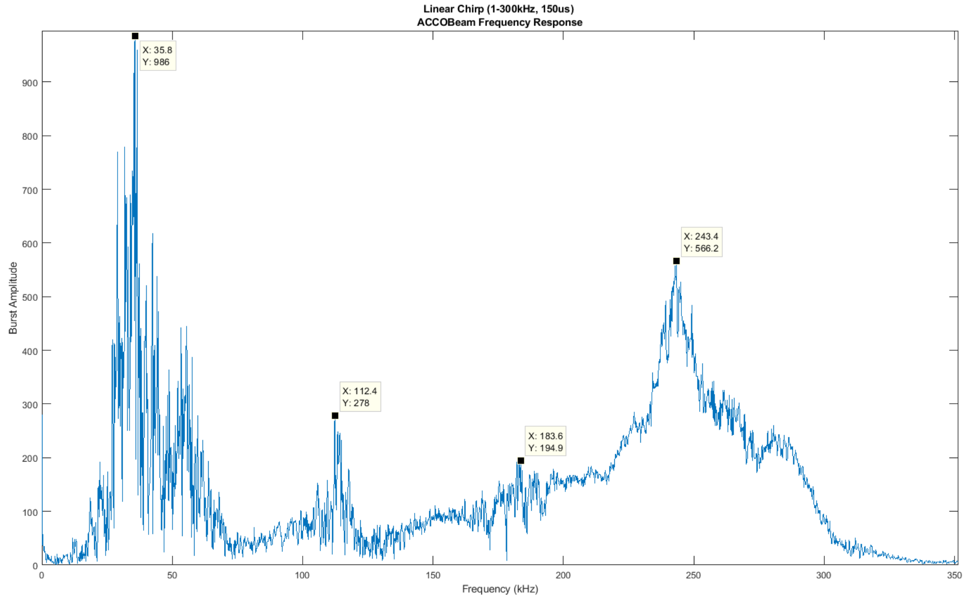
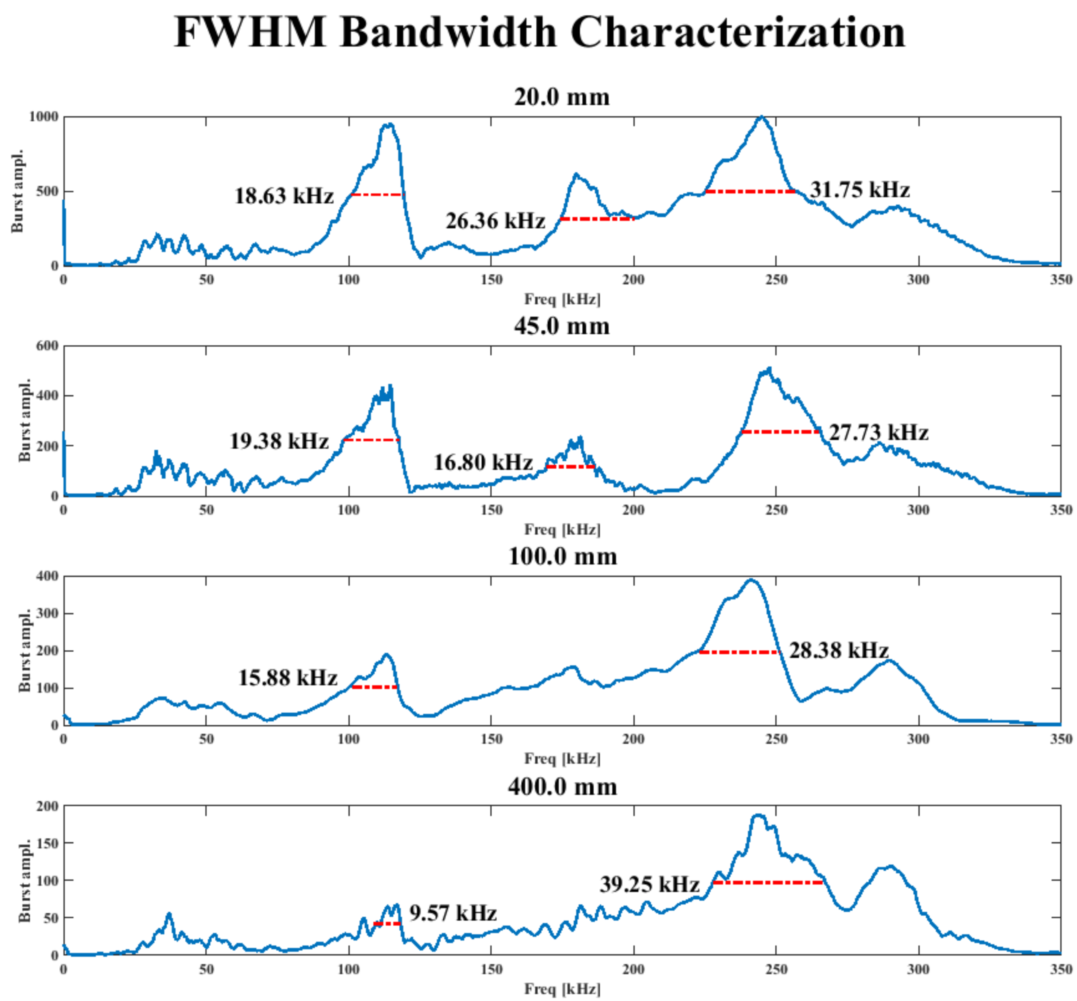
Broadband Operation

- Bandwidth of operation
  - Full width at half maximum (FWHM) characterization changes with distance
  - For further distances, the 4th mode dominates the 3rd and merge together



Broadband Operation



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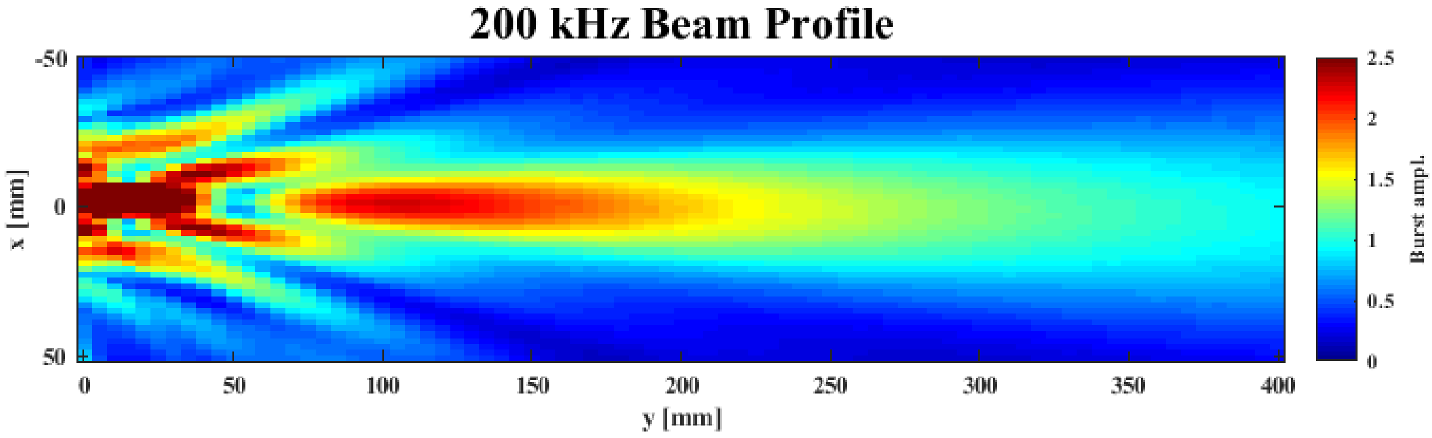
Broadband Operation

- First resonant mode (34 kHz) is difficult to excite with a linear chirp because of low number of cycles achievable in the burst duration
- Gaussian pulse is significantly faster than the linear chirp, though overall weaker
- Intermediate frequencies yield strong beams (3^{rd}-4^{th})



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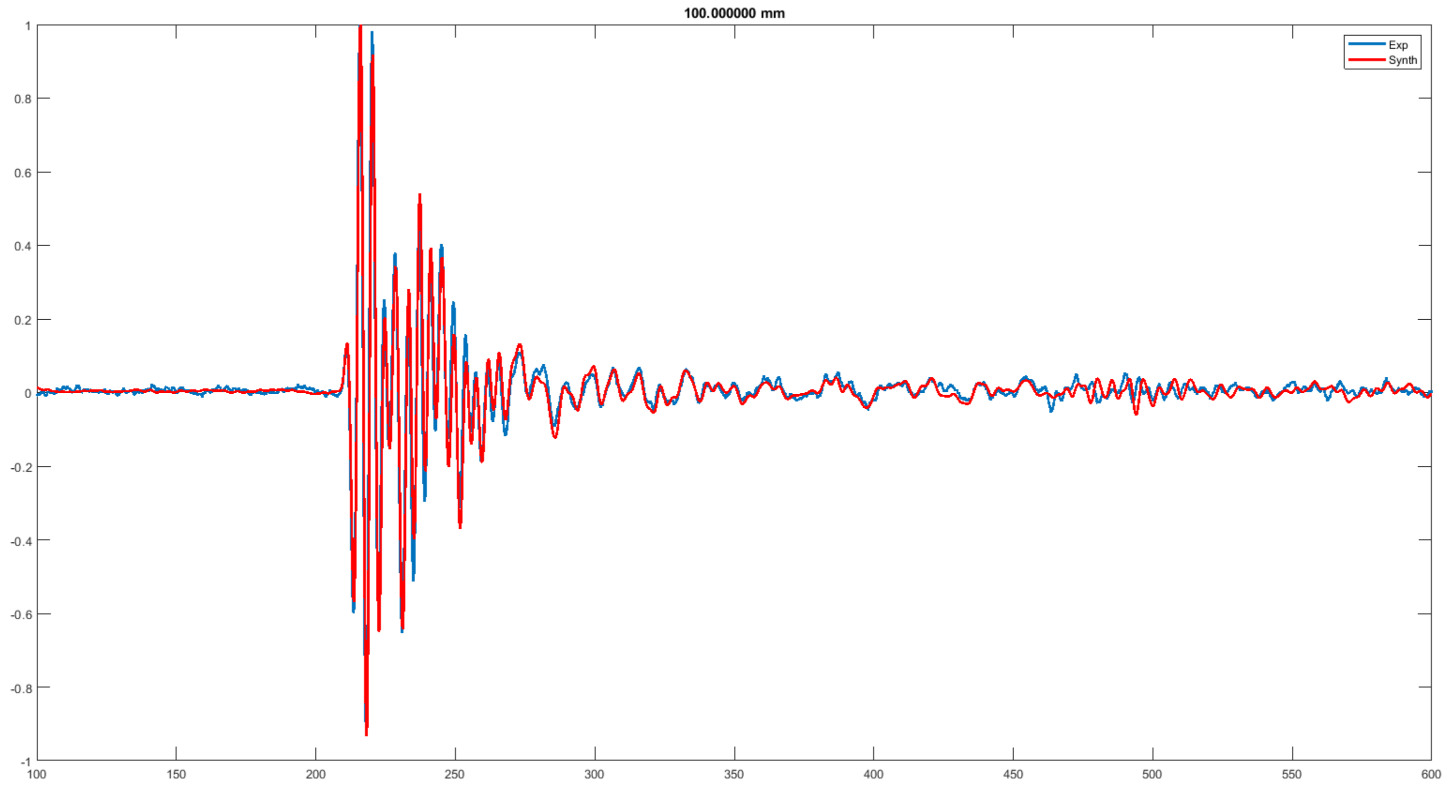
Reconstructing Data for Arbitrary Input from Linear Chirp Data

- The input $x(t)$ and output $y(t)$ of a LTI system are related by the transfer function:

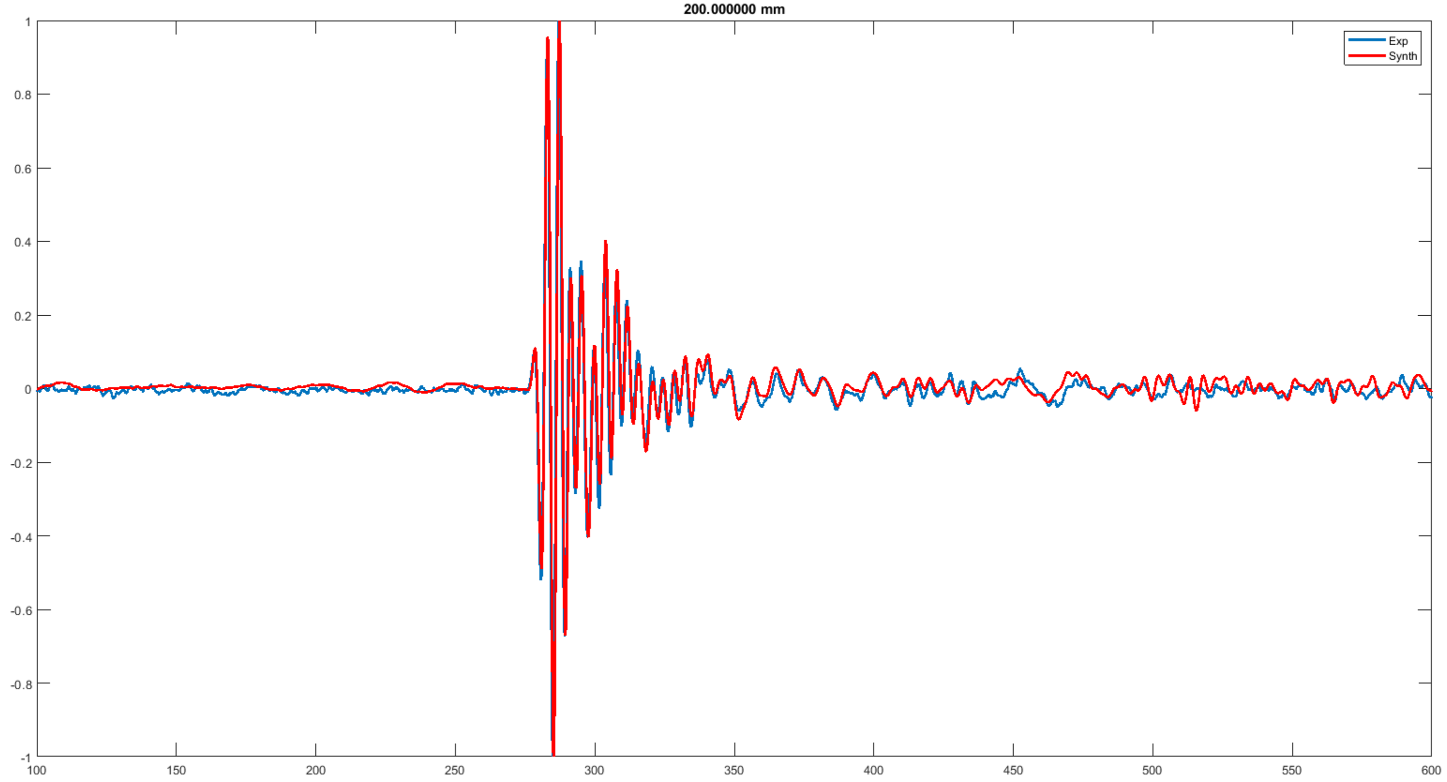
$$y(t) = h(t) \star x(t) \overset{\mathcal{F}}{\leftrightarrow} Y(\omega) = H(\omega)X(\omega)$$

- Using the experimental linear chirp data, we can find the transfer function
  - Given some input $x_{synth}(t)$, we can find $y_{synth}(t)$
  - With knowledge of $y_{goal}(t)$, we can find a $x_{goal}(t)$
- Transfer function only valid for window region of chirp data

Reconstructing Data – Preliminary Results



Reconstructing Data
– Preliminary Results



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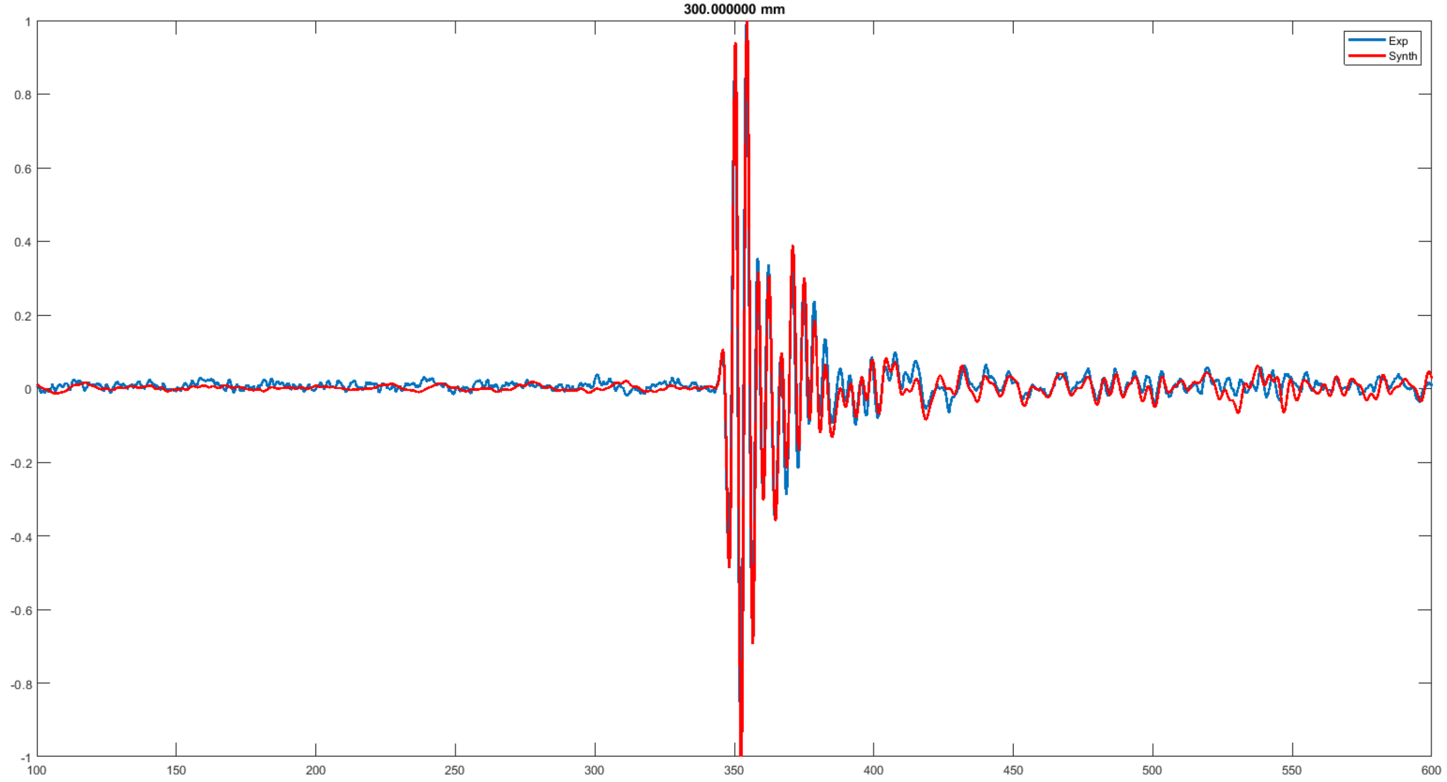

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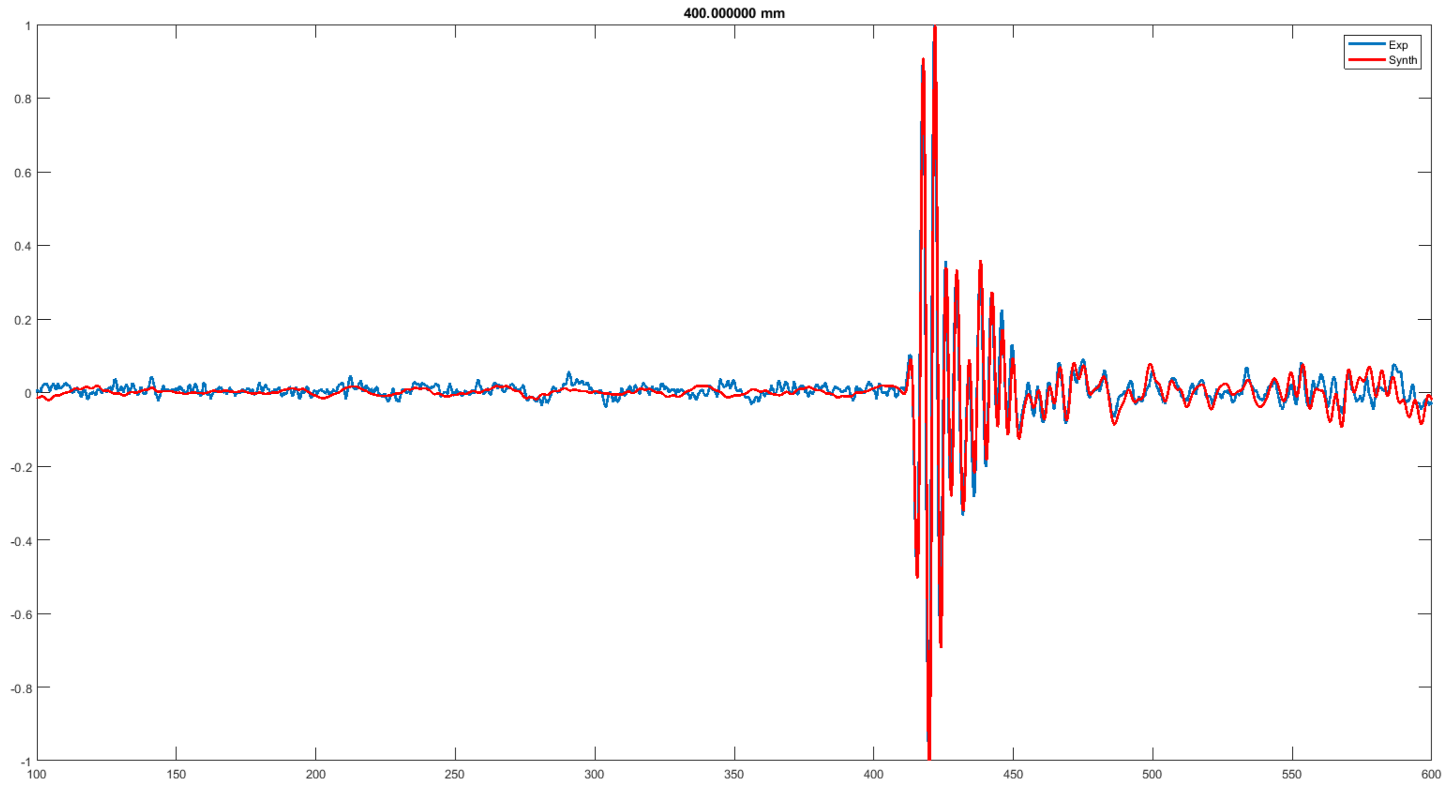
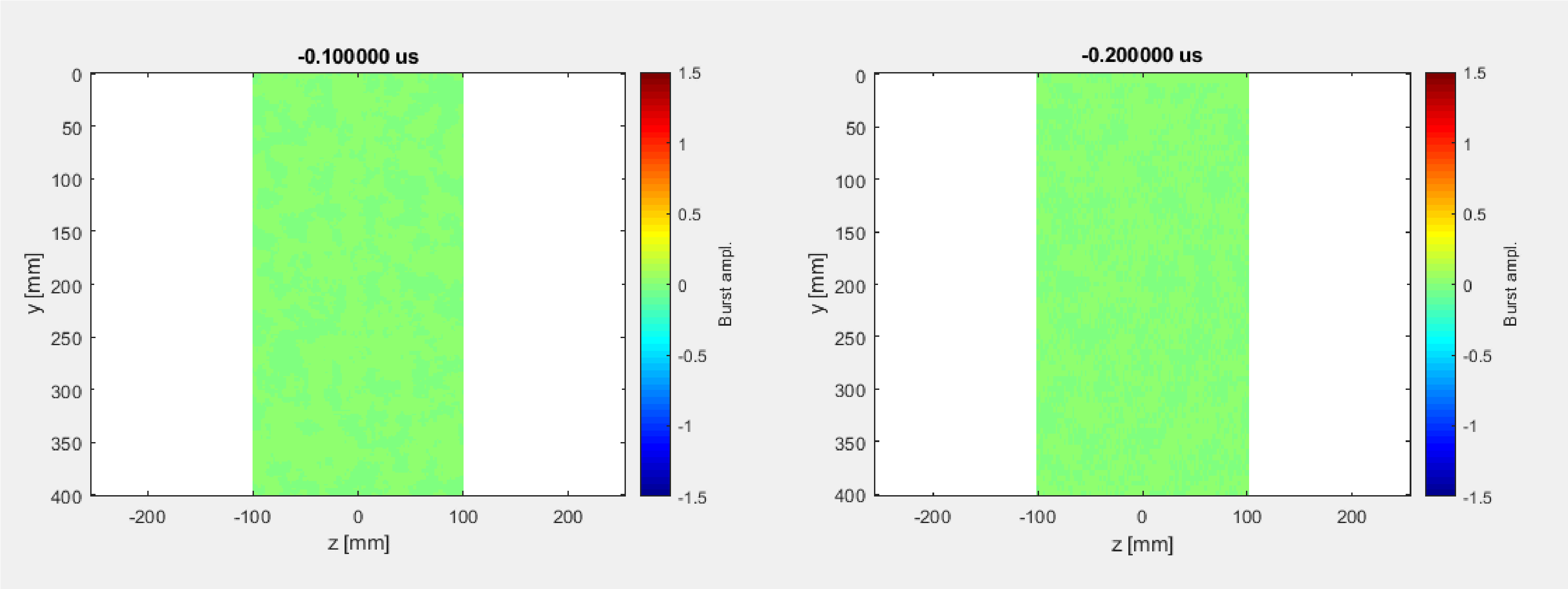


Reconstructing Data
– Preliminary Results



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Acknowledgements

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